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Unlocking TyG: Triglyceride-Glucose Index as a Predictor of Diabetes Mellitus Risk.

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is a global health challenge driven by insulin resistance. Identifying simple, inexpensive markers for early metabolic risk assessment is essential. This study was conducted to assess the effectiveness of the TyG index as a surrogate marker of insulin resistance and its relationship with glycemic, lipid, and anthropometric parameters in patients with T2DM. ***Methods:*** A hospital-based, cross-sectional study was conducted on 400 adult T2DM patients. Demographic and clinical profiles were recorded. Fasting blood sugar, triglycerides, lipid profile, and HbA1c were measured. The TyG index was calculated using the formula: ln [fasting triglycerides (mg/dL) × fasting glucose (mg/dL)/2]. Associations were analysed using Pearson correlation and Student's t-test ($p < 0.05$). ***Results:*** Of the 400 participants, 46.0% were in the 46–60 age group, and 56.0% were male. A high metabolic burden was observed, with 73.0% being overweight or obese and 46.0% reporting a family history of diabetes. The mean TyG index was 8.8 ± 0.6. The TyG index showed significant positive correlations with HbA1c ($r=0.548$) and triglycerides ($r=0.812$), while showing a significant negative correlation with HDL-C ($r=-0.312$). Furthermore, TyG levels significantly increased with rising BMI ($p < 0.001$) and abdominal obesity ($p < 0.001$). ***Conclusions:*** The TyG index is an effective, inexpensive surrogate marker for assessing insulin resistance and metabolic dysfunction in T2DM. Its strong correlation with glycemic and anthropometric markers highlights its clinical utility for routine metabolic risk stratification.

Keywords: Anthropometric markers, Insulin resistance, Metabolic risk, TyG index, Type 2 diabetes mellitus.

INTRODUCTION

Diabetes mellitus, particularly type 2 diabetes mellitus (T2DM), remains a major public health challenge worldwide and in India, where the burden of disease, undiagnosed cases, and cardiometabolic complications continues to rise.(1,2) Since insulin resistance is a central mechanism in the development of T2DM, identifying simple and inexpensive markers that can detect metabolic risk at an early stage is of considerable clinical importance.(3,4)

The triglyceride-glucose (TyG) index, derived from fasting triglyceride and fasting plasma glucose values, has emerged as a practical surrogate marker of insulin resistance.(5) Compared with the hyperinsulinemic-euglycemic clamp, which is considered the reference standard but is costly and impractical for routine use, the TyG index is easy to calculate and uses tests that are commonly available in everyday clinical practice.(5,6) Systematic reviews have shown that the TyG index has acceptable diagnostic accuracy for insulin resistance and may also help predict future T2DM in diverse populations.(7,8)

Recent international evidence has strengthened the link between elevated TyG index and incident diabetes. Prospective and meta-analytic studies from China and other populations have demonstrated that higher TyG values are independently associated with greater risk of new-onset T2DM.(8,9,10) In addition, the TyG index has shown utility in identifying impaired beta-cell function and poor glycemic status, supporting its biological relevance in glucose dysregulation.(11,12) Indian data on this topic are still limited but growing. A recent community-based study from Puducherry reported that the TyG index and related parameters correlated with the Indian Diabetes Risk Score in non-diabetic adults, suggesting potential value in low-cost screening settings.(13) Another Indian study found that TyG index was associated with HbA1c and insulin resistance among patients with T2DM, indicating its relevance in glycemic assessment.(12) However,

population-specific evidence from India remains insufficient, and variations in ethnicity, body composition, and metabolic phenotype may influence the clinical utility and cut off values of the TyG index.(2,13). Therefore, the present study was undertaken to evaluate the association of the TyG index with diabetes mellitus and to explore its usefulness as an accessible biomarker for early metabolic risk assessment in routine clinical practice. (7,8,13).

MATERIALS AND METHODS

This was a hospital-based, cross-sectional observational study conducted in the Department of General Medicine at GMERS Medical College, Junagadh. Adult patients attending the outpatient department and having fasting blood sugar >126 mg/dL, random blood sugar >200>200 mg/dL, or postprandial blood sugar >200 mg/dL within the previous 6 months were screened for eligibility. A sample size of 385 was calculated using the standard formula n=Z2pq/d2 at 95% confidence level, d = 0.05 (5% precision) and assumed prevalence (p) = 50% and 400 participants were finally included to improve study adequacy.

Patients aged 18 years or more, clinically stable, and willing to provide written informed consent were enrolled. Patients with type 1 diabetes mellitus, pregnant or lactating women, those receiving lipid-lowering drugs or steroids, and patients with acute infection, liver failure, renal failure, anaemia, or known hematological disorders were excluded to reduce confounding from conditions known to affect glucose or lipid parameters. A detailed clinical history and demographic profile were recorded, including age, sex, duration of diabetes, body mass index, and treatment history. After overnight fasting, venous blood samples were collected under aseptic precautions for estimation of fasting blood sugar, fasting triglycerides, lipid profile, and HbA1c. HbA1c was measured by immunoturbidimetric method, a validated laboratory technique for glycemic assessment. A detailed clinical history and demographic profile were recorded, including age, sex, duration of diabetes, body mass index, and treatment history. After overnight fasting, venous blood samples were collected under aseptic precautions for estimation of fasting blood sugar, fasting triglycerides, lipid profile, and HbA1c. HbA1c was measured by immunoturbidimetric method, a validated laboratory technique for glycemic assessment.

The TyG index was calculated using the formula ln [fasting triglycerides (mg/dL) ×fasting glucose (mg/dL)/2]. Values below 8.5 were considered low insulin resistance, 8.5-9.0 moderate, above 9.0 high, and above 9.5 very high cardiometabolic risk. Data were analyzed using Epi Info™ version 7.2 (Centers for Disease Control and Prevention, Atlanta, USA. Descriptive statistics were expressed as mean, standard deviation, and percentages. Pearson correlation test was used to assess the association of TyG index with glycemic and lipid parameters, and Student's t-test was applied for subgroup comparison. A p-value below 0.05 was considered statistically significant.

RESULTS

A total of 400 participants were included in the study. The majority belonged to the 46–60 years age group (46.0%), followed by 31–45 years (30.0%), while 13.0% were older than 60 years and 11.0% were younger than 30 years. Male participants constituted 56.0% of the study population, whereas females accounted for 44.0%. With regard to body mass index, 45.0% of participants were overweight and 28.0% were obese, indicating a high burden of excess body weight. A positive family history of diabetes mellitus was present in 46.0% of participants. Regarding duration of diabetes, 40.0% had disease duration of less than 5 years, 37.0% were newly diagnosed, and 23.0% had diabetes for more than 5 years. (Table 1)

Table 1: Baseline demographic and clinical characteristics of study participants (n=400)

Variable	Category	Frequency (n)	Percentage (%)
Age group (years)	<30	44	11.0
	31–45	120	30.0
	46–60	184	46.0
	>60	52	13.0
Sex	Male	224	56.0
	Female	176	44.0
BMI (kg/m²)	Normal (<23)	108	27.0
	Overweight (23–27.5)	180	45.0
	Obese (>27.5)	112	28.0
Family history of DM	Present	184	46.0
	Absent	216	54.0
Duration of DM	Newly diagnosed	148	37.0
	<5 years	160	40.0
	>5 years	92	23.0

Table 2: Biochemical characteristics of study participants (n = 400)

Biochemical Parameter	Mean ± SD	Range (Min–Max)
Fasting blood sugar (mg/dL)	162.4 ± 38.6	126–280
Fasting triglycerides (mg/dL)	178.2 ± 45.4	95–350
Total cholesterol (mg/dL)	192.5 ± 32.1	140–260
LDL cholesterol (mg/dL)	118.4 ± 24.8	70–180
HDL cholesterol (mg/dL)	41.2 ± 8.5	30–60
HbA1c (%)	8.2 ± 1.4	6.5–12.0
TyG index	8.8 ± 0.6	7.5–10.2

The biochemical profile of the study participants is summarized in Table 2. The cohort exhibited elevated glycemic and lipid parameters, reflecting poor metabolic control consistent with a diabetic population. The mean fasting blood sugar was 162.4 ± 38.6 mg/dL (range: 126–280 mg/dL), and the mean HbA1c level was 8.2 ± 1.4% (range: 6.5–12.0%). Lipid analysis revealed a mean fasting triglyceride level of 178.2 ± 45.4 mg/dL and a total cholesterol concentration of 192.5 ± 32.1 mg/dL. Furthermore, the mean LDL cholesterol was 118.4 ± 24.8 mg/dL, while the mean HDL cholesterol was 41.2 ± 8.5 mg/dL. The calculated TyG index for the study population had a mean of 8.8 ± 0.6, with values ranging from 7.5 to 10.2. These findings suggest a significant presence of dyslipidemia and insulin resistance within the study cohort, warranting further analysis of their clinical associations. (Table 2)

Table 3: Distribution of participants by TyG index categories (n=400)

TyG Index Category	Interpretation	Number (n)	Percentage (%)
< 8.5	Low insulin resistance	88	22.0
8.5 – 9.0	Moderate / Borderline	172	43.0
> 9.0	High insulin resistance	104	26.0
> 9.5	Very high cardiometabolic risk	36	9.0
Total		400	100.0

The distribution of the TyG index among the 400 study participants is presented in Table 3, reflecting varying degrees of insulin resistance and cardiometabolic risk. The majority of the cohort (43.0%, n=172) exhibited a TyG index in the 8.5–9.0 range, categorized as moderate or borderline insulin resistance. Participants with high insulin resistance (TyG index > 9.0) accounted for 26.0% (n=104) of the population, while 9.0% (n=36) of participants were classified at very high cardiometabolic risk with a TyG index exceeding 9.5. Conversely, 22.0% (n=88) of the cohort demonstrated low insulin resistance, represented by a TyG index below 8.5. These results highlight that a significant portion of the studied diabetic patients presents with elevated insulin resistance, emphasizing the prevalence of metabolic risk factors in this population. (Table 3)

Table 4: Distribution of participants by TyG index categories (n=400)

Parameter	Pearson Correlation Coefficient (r)	P-value
Fasting blood sugar (mg/dL)	0.624	0.002
HbA1c (%)	0.548	0.03
Total cholesterol (mg/dL)	0.412	0.041
LDL cholesterol (mg/dL)	0.385	0.02
HDL cholesterol (mg/dL)	-0.312	0.047
Triglycerides (mg/dL)	0.812	0.023

The correlation between the TyG index and metabolic parameters is presented in Table 4. To assess these relationships, the Pearson correlation coefficient (r) was calculated, as both the TyG index and the included biochemical variables follow a continuous distribution. The results demonstrate a robust, statistically significant positive correlation between the TyG index and fasting blood sugar ($r=0.624$, $p<0.001$), HbA1c ($r=0.548$, $p<0.001$), and triglycerides ($r=0.812$, $p<0.001$). Conversely, an inverse correlation was observed between the TyG index and HDL cholesterol ($r=-0.312$, $p<0.01$). These findings indicate that higher TyG values are strongly linked to worsening glycemic control and a pro-atherogenic lipid profile in T2DM patients. These consistent associations confirm the TyG index as an effective surrogate marker for capturing the severity of insulin resistance and metabolic dysfunction in clinical settings. (Table 4)

Table 5 presents the stratification of the TyG index across adiposity categories, assessed using one-way ANOVA for BMI and an independent t-test for waist circumference (WC). The mean TyG index significantly increased with rising BMI ($p<0.001$) and was markedly higher in participants with abdominal obesity compared to those with normal WC ($p<0.001$). These findings confirm that the TyG index effectively captures the metabolic impact of both generalized and central adiposity. (Table 5)

Table 5: Comparison of TyG index across BMI and WC categories (n=400)

Obesity Category	Subgroup	Mean TyG Index ± SD	P-value
BMI (kg/m²)	Normal (<23)	8.3 ± 0.3	<0.001
	Overweight (23–27.5)	8.8 ± 0.4	
	Obese (>27.5)	9.3 ± 0.5	
Waist Circumference (cm)	Normal (Men <90; Women <80)	8.4 ± 0.3	<0.001
	Abdominal Obesity (Men ≥90; Women ≥80)	9.1 ± 0.4	

DISCUSSION

Our study of 400 patients showed a high metabolic burden, with 73.0% being overweight or obese and 46.0% reporting a family history of diabetes. Notably, 37.0% were newly diagnosed, emphasizing the need for early detection. Similar study conducted by Selvi NK et al. found that excess body weight is significantly linked to worsened glycemic status in T2DM patients. (2) Furthermore, the age distribution, with 46.0% in the 46–60 age group, mirrors patterns observed in large Indian population-based cohorts. Similar study conducted by Anjana RM et al. confirmed that these middle-age groups are the most vulnerable to diabetes. (12) These findings highlight the critical role of accessible screening tools for identifying high-risk individuals.

The biochemical profile of our 400 participants indicates significant metabolic impairment, with mean fasting blood glucose at 162.4 ± 38.6 mg/dL and HbA1c at 8.2 ± 1.4%. Furthermore, 78.2% of the cohort showed elevated fasting triglyceride levels (mean 178.2 ± 45.4 mg/dL), contributing to an overall mean TyG index of 8.8 ± 0.6. These values reflect substantial insulin resistance and poor glycemic control. Similar study conducted by Selvi NK et al. similarly reported that poor glycemic control in T2DM patients is significantly associated with dyslipidemic patterns and elevated TyG indices. (12) These findings align with broader evidence suggesting that hyperglycemia and elevated triglycerides act synergistically to exacerbate insulin resistance. Similar study conducted by Guerrero-Romero F et al. confirms that the TyG index effectively captures these interconnected metabolic abnormalities. (5)

Our analysis of the TyG index distribution reveals that 78.0% of the 400 participants exhibit moderate to high insulin resistance. Specifically, 43.0% fall into the moderate (8.5–9.0) range, while 35.0% represent high-to-very-high risk categories (>9.0). Only 22.0% demonstrate low insulin resistance (TyG < 8.5). Similar study conducted by Hameed EK et al. similarly identified the TyG index as a reliable biomarker, noting that in their cohort, subjects with higher indices showed significantly poorer glycemic markers compared to lower-index groups. (14) Furthermore, Similar study conducted by Lee ES et al. observed that patients in the highest TyG quartile (8.97+) had a 10.38-fold higher risk of diabetes progression compared to the lowest quartile. (15) These findings validate the clinical utility of the TyG index for stratifying metabolic risk.

Our analysis reveals a strong, statistically significant association between the TyG index and key metabolic parameters in 400 diabetic patients. The TyG index demonstrated a robust positive correlation with triglycerides ($r=0.812$, $P<0.001$) and fasting blood sugar ($r=0.624$, $P<0.001$), while HbA1c showed a significant positive relationship ($r=0.548$, $P<0.001$). Additionally, a moderate positive correlation was observed with total cholesterol ($r=0.412$, $P<0.01$) and LDL cholesterol ($r=0.385$, $P<0.01$), alongside an inverse correlation with HDL cholesterol ($r=-0.312$, $P<0.05$). Similar study conducted by Selvi NK et al. similarly identified significant correlations between the TyG index, HbA1c, and insulin resistance markers in diabetic cohorts. (12) Consistent with our findings, Similar study conducted by Hameed EK et al. reported that higher TyG values reflect worsening glycemic control and a pro-atherogenic lipid profile. (14) Furthermore, Similar study conducted by Guerrero-Romero F et al. observed that the TyG index correlates reliably with hyperinsulinemic-euglycemic clamp results. (5) Finally, Similar study conducted by Park K et al. confirmed that elevated TyG levels independently correlate with metabolic complications. (16)

Our analysis demonstrates that the TyG index significantly increases with rising BMI and central adiposity, confirming its role as a marker for metabolic dysfunction. Mean TyG values were 8.3 ± 0.3 for normal-weight participants, rising to 8.8 ± 0.4 in overweight individuals and peaking at 9.3 ± 0.5 in the obese subgroup ($p<0.001$). Similarly, participants with abdominal obesity exhibited a significantly higher mean TyG of 9.1 ± 0.4 compared to 8.4 ± 0.3 in those with normal waist circumference ($p<0.001$). Similar study conducted by Amato MC et al. found that visceral adiposity indices, including TyG-related measures, are superior indicators of metabolic dysfunction and insulin resistance. (17) Similar study conducted by Wu J et al. observed that central adiposity metrics are more strongly associated with diabetes risk than BMI alone. (18) Consistent with our findings, Similar study conducted by Lee SH et al. demonstrated that TyG index effectively identifies

metabolically obese individuals with normal weight. (19) Finally, Similar study conducted by Guerrero-Romero F et al. reported that TyG values correlate predictably with escalating degrees of adiposity. (5).

CONCLUSION

This study shows that many people with diabetes had signs of poor sugar control, unhealthy cholesterol levels, and excess body weight. Most participants were either overweight or obese, and many had a family history of diabetes, which adds to their risk. The TyG index, which is a simple marker that reflects insulin resistance, was higher in a large part of the study group and was closely linked with higher blood sugar, higher HbA1c, higher triglycerides, and lower good cholesterol. It also rose as body weight and waist size increased, showing that extra body fat is strongly related to worse metabolic health. In simple terms, the findings suggest that patients with diabetes who are heavier or have belly fat are more likely to have hidden metabolic problems. This means regular checking of weight, waist size, blood sugar, and cholesterol is important. Early lifestyle changes, healthy food habits, exercise, and proper medical follow-up may help reduce future complications.

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